



Curing of powder lacquers in seconds

With a new dryer, which works with short-wave radiation, a homogeneous heating of the powder layer to a curing temperature is attained in a few seconds. Since the substrate to be coated is thereby heated only a little, the new dryer is also ideal for the powder coating of wood and plastics.

The above-average increase in the use of water and powder lacquers requires a constant optimization and further development, both of the coating substances as well as the application and drying technologies.

The IndustrieSerVis Company in Bruckmühl has developed a novel drying technology, which makes possible the crosslinking of powder lacquers within only a few seconds.

In this way, new optimized process sequences are made possible, in particular, with water lacquers and powder systems for the treatment of temperature-sensitive substrate materials (such as wood and plastic) and contoured surfaces by:

- ☐ drying or crosslinking in a cycle of seconds;
- ☐ focussing via reflector systems;
- ☐ in-line process monitorings; and
- ☐ compact unit technology.

This article describes the new drying or crosslinking method, with which an extremely short curing time can be attained with a minimized substrate heating, with powder coatings, by means of a high power density and penetration depth. This is made possible by the combination of high-performance infrared radiation sources and focussing reflector systems.

The curing and crosslinking reaction

The mechanism of the curing and crosslinking reaction of most powder lacquers takes place, as a function of the temperature, according to kinetic laws in the individual reaction systems. During the baking, the powder coating should be brought to the necessary curing temperature,

homogeneously and as quickly as possible, over the layer thickness down to the substrate surface. Only in this way can the powder lacquer melt attain the minimum viscosity, without considerably being hindered with respect to flow by crosslinking reactions. With a slower heating, the coating material crosslinks, without having flowed sufficiently, which results in an unevenness of the surface due to a non-optimal flow of the powder.

Constant baking parameters over a temperature-supervised heating process lead to constant gloss degrees and prevent an excess baking of the coating. Depending on the powder system, the baking temperatures lie between 120°C and 300°C. As a result of the high temperature, up to now, temperature-sensitive substrates were accessible to the powder lacquering only in a limited manner. The new focussing drying technology offers new perspectives in this application segment.

Drying with "near-infrared"

During infrared heating, the thermal energy is transferred by means of electromagnetic waves. The infrared radiation spectrum extends from 0.76 μm to 1000 μm . With NIR technology (near-infrared), the infrared radiation spectrum is used close to the visible light spectrum between 0.76 μm and 1.2 μm .

Highest energy density

In accordance with the Stefan-Boltzmann law, the energy transfer of the radiation is proportional to the difference of the fourth power of the coil and the object temperature. This means that an increase in the radiator temperature leads to a far greater increase in the energy transfer. The released radiation intensity increased with [by] T^4 .

Moreover, the position of the radiation maximum shifts, in accordance with Wien's displacement law, in the direction of shorter wavelengths, with increasing temperature.

Planck's radiation formula describes the spectral distribution of the radiation density of a black radiator--that is, of a radiation source that absorbs 100% of the striking radiation. Figure 2 shows the isotherms of Planck's radiation formula over the IR range.

One can see that a radiator, at a temperature of 3000 K, in the range of NIR radiation, attains a very much higher radiation intensity than a radiator at 1800 K, in the medium-wave IR range. Thus, it is possible, with such radiators, to attain extremely high energy densities (by more than one order of magnitude higher than with conventional systems).

With NIR technology, high-power halide lamps, which operate at coil surface temperatures of up to 3500 K, are used as the actual radiation source.

Quick regulation capacity

As a result of the high, transferred power density with the new technology, a temperature-controlled heating of the object via a regulation of the radiators is required.

The low mass of the heating coil has the advantage that the radiation systems react spontaneously to current fluctuations and can react extremely quickly. The heating source reaches the full radiation power within a very short time, and is just as quickly turned off.

The primary process variable is the surface temperature of the objects to be heated, which is recorded in a contactless mode by means of radiation pyrometers, especially adapted to the radiation characteristics. In this way, a closed-loop regulation can be implemented. The rapid response time of the new system, in combination with the contactless energy transfer, permits a rapid regulation of the process and thus makes possible an automated process control.

Optimal contour adaptation

The radiation emitted in the NIR spectral range can be oriented very efficiently by means of special reflector systems. Depending on the surface contour to be heated, the radiation can be purposefully bundled via parabolic reflectors so that it can be applied homogeneously over the entire surface with extremely high radiation densities.

This makes possible a purposeful heating of surfaces as well as the intensity bundling on lines and points. In this way, a homogeneous energy density can be produced over a contoured surface. Moreover, the radiation focussing with re-entrant angles is also possible by means of specially shaped reflector systems.

Crosslinking in a cycle of seconds

In conventional crosslinking methods for thermoreactive powders, the necessary curing temperature is attained via multistage energy transfers. First, the surface of the powder coating is heated by means of IR radiation or by convection. Only then does the thorough heating take place in the powder layer via a thermal conduction process down to the substrate boundary layer. There, the energy, especially with metal substrates, is very quickly transferred into the substrate via the higher

thermal conduction. Only with a more complete thorough heating of the substrate does the boundary layer attain the needed crosslinking temperature.

The new drying technology, on the other hand, leads the energy needed for the crosslinking, directly and homogeneously, over the layer thickness, into the powder layer. As a function of the degree of transmission of the powder and of the degree of reflection of the boundary layer in the emitted wavelength range, heating to a certain depth can be purposefully established.

In the conventional method, only the temperature gradient between the coating surface and the substrate represents the driving process variable for the thorough heating of the coating. In order to guarantee a homogenous film formation and crosslinking, and thus a satisfactory adhesion, heating times of several minutes are necessary.

As a result of the high radiation density and the depth effect of the NIR technology, a homogeneous heating of the coating to the curing temperature is attained in a few seconds.

The rapid attainment of the needed threshold temperature within approximately five seconds is striking. In this way, a crosslinking of the powder is started, after the coating material has flowed, for the most part. For the complete crosslinking of the powder lacquer film, the temperature must be kept on the object for another few seconds, independent of the powder system. After the cooling, the coating is then cured.

These enormously shortened crosslinking times permit the conclusion that with the NIR technology, the emitted radiation, in addition to the temperature activation of the powder, directly triggers the reaction of the binder or accelerates the started reaction. Other purposeful investigations for the optimized process design must still be carried out. The experiments that have been carried out up to now document the possible acceleration of the crosslinking process of powder coatings, shown in Figure 5.

Connected with the more rapid crosslinking are correspondingly smaller unit dimensions. As a result of the compact mode of construction of the new drying system, there is a substantially smaller number of parts in the process so that coating errors or errors in the unit adjustment are thus recognized earlier and costs for readjustment operations can therefore be reduced.

High coating quality

The powder coatings cured with near-infrared rays are in no way inferior to the conventionally crosslinked coatings with respect to the flow, the adhesion, and the degree of gloss as

a result of the quick and homogeneous heating. The attained high crosslinking density leads to a high product quality (wear resistance, hardness, chemical resistance). There are no blow-off effects as with circulation furnaces. The temperature-controlled process control also prevents digester formation and an overheating of the powder.

Ideal for drying temperature-sensitive substrates

For a complete crosslinking and an optimal adhesion on the substrate, obtaining a homogeneous temperature in the powder and boundary layer is necessary. As a result of the high radiation density and the effective depth heating, the introduction of heat into the coating system is higher than the heat removal even of a metal substrate. Therefore, the ideal crosslinking state can be attained very much earlier than with the conventional treatment, even if the substrate is still not completely and thoroughly heated. From this, there are, in addition to the already mentioned time advantages, considerable savings in energy, especially with very thick-walled objects or substrates made of solid materials.

With the aid of the near-infrared technology, it is possible to coat temperature-sensitive substrates, such as plastics or wood, with thermoreactive powders. Preliminary experiments have shown that the NIR radiation activates the plastic surface through the powder layer. In this way, a sufficient lacquer adhesion is attained, without having to carry out a flaming or a plasma pretreatment step before the powdering.

Powder coating of wood and plastics

The new drying technology offers new possibilities for using powder lacquer for coating in the plastic or wood-processing industry.

The temperature-regulated crosslinking in a cycle of seconds, the homogeneous energy introduction into the coating system, adapted to the component, and the compact and modular unit technology also make possible new optimized process sequences in already existing unit systems.

For the testing of these new usage possibilities in a situation close to production and for research and development tasks, the experimental and development laboratory of the IndustrieSerVis Company was expanded by a pilot plant unit.

In the unit, it is possible to apply both wet and powder lacquers, and subsequently to dry or crosslink them in an NIR heating system. A flexible transport system for changing the configurations

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of parts, an application and heating program, and the automated control provide for a situation such that one can set up and go through the process parameters in a reproducible manner.

By means of a video monitoring system, integrated into the unit, the process quality attained on the lacquered test specimen is documented. Thus, possible deviations in the coating process can be detected inline.

With the described pilot plant unit, the IndustrieSerVis Company has produced for itself instruments that make possible the determination of the process and production-relevant parameters already in the experimental phase and thus provide the basis for a unit conception before the projection phase.

Summary

The new drying technology provides an ideal possibility to crosslink powder coatings quickly and efficiently. The high, attainable radiation densities permit a compact system structure and offer a clear increase in performance in comparison to conventional heating systems. Crosslinking times of only a few seconds are implemented. In addition, it is possible to crosslink coatings on heat-sensitive substrates.

The focussing systems permit a purposeful heating, adapted to the configuration of the parts. A homogeneous introduction of energy over a contoured surface can be implemented with the aid of these reflector systems. As a result of the depth effect of the short-wave radiation, a constant temperature course is produced over the layer thickness.

The quick response time of the NIR system, in combination with the contactless temperature measurement, permits a precise process regulation. On the basis of the new technology, preliminary production units for water[-based] lacquer systems are successfully in use. For powder systems, demonstration results are already available and, at the moment, various industrial application cases are being projected. The experience currently available confirms the excellent usage potential for NIR technology, in particular, with regard to new optimized process sequences in paint, lacquer, and powder coating technology.